Water quality evaluation through limnologic survey in a fish culture system in the Paranaíta region (Mato Grosso, Brazil).

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ABSTRACT: Water quality evaluation through limnologic survey fish culture system in the Paranaíta region (Mato Grosso, Brazil). Current study evaluates water quality of a fish farm, compares reservoirs with and without water flow and estimates the consequences of discharging into the receiving water body. In general, limnological variables were higher in the reservoir without water flow and presented high concentrations of nutrients during the experimental period. In the reservoir with continuous water flow the variables were not significantly different ($p > 0.05$). Significant alterations were observed ($p < 0.05$) during the dry period for ammonia concentrations at the fish farm outlet, preceding its discharge in the river; nevertheless, no influence on the river water quality has been reported. This is probably due to the amount of aquatic plants in the channel which discharges into the river Porto de Areia, transformed into a wetland. Greatest changes in variables have been reported during the dry season. Fish farm management has contributed towards a rise in environmental variables, with modifications in the quality of the effluent.

Key-words: fishponds, water quality, morphometry, effluent.

RESUMO: Avaliação da qualidade da água, através de levantamento limnológico em sistema de piscicultura na região de Paranaíta (Mato Grosso, Brasil). O objetivo deste trabalho foi avaliar a qualidade da água de um sistema de produção de peixes, comparando as represas de cultivo com e sem fluxo de água bem como, a influência do efluente no corpo de água receptor. De maneira geral, as variações limnológicas foram maiores na represa com sistema estagnado, apresentando elevadas concentrações de nutrientes durante o período de despesca. Na represa, com fluxo contínuo de água, as alterações não foram estatisticamente relevantes ($p > 0{,}05$). Na saída do sistema de produção, antecedendo sua descarga no rio, foi observada alteração significativa ($p < 0{,}05$) no período de seca em relação a amônia, porém, não influenciou a qualidade da água do corpo receptor, provavelmente, devido a grande quantidade de macrófitas existentes no canal condutor da descarga até o rio Porto de Areia, funcionando como biofiltro ("wetland"). Entretanto, o fósforo total, ortofosfato, alcalinidade e dureza, mesmo que estatisticamente não tenha sido significativo ($p > 0{,}05$) quanto à alteração da qualidade da água do rio, apresentaram alterações em relação ao sistema de produção. As maiores alterações nas variáveis estudadas foram observadas durante o período de seca e o manejo empregado na piscicultura, contribuiu para a elevação das variáveis ambientais alterando a qualidade do efluente.

Palavras-chave: viveiros, qualidade da água, morfometria, efluente.

Introduction

Fish culture has recently made great strides in the region of Paranaíta (Mato Grosso, Brazil), with river enrichment and changes in biotic and abiotic conditions. Obviously, constant control of water quality in fishponds is needed. Success of fish culture greatly depends on the choice of site on which the project may be developed and on several environmental factors, especially quantity and quality of water, soil, topography and climate (Boyd & Queiroz, 2004), which must be analyzed prior to its undertaking.

Needless to say, the type of available water is one of the most significant factors to be taken into account in the choice of the site, which actually determines the fish population to be stocked. Although water from rivers, streams and reservoirs are the most common, the quality and the quantity of the available water is of paramount importance in fishpond production biomass since profits depends on them (Boyd, 2003). Inadequate use of nutrient-rich compounds associated to improper biotic and abiotic conditions may cause damage to the environment and impair financial assets (Mainardes-Pinto & Mercante, 2003). Information on fishpond dynamics depends basically on the study of interactions between environmental variables, management and fish species, which are the main factors for the sustainability of aquaculture (Sipaúba-Tavares & Gaglianone, 1993).

Although in the northern region of the state of Mato Grosso, Brazil, data on specific conditions, such as contamination of water resources by cattle-raising activities, river silting, lack of riparian vegetation, types of soil culture, tourist activities on fish angling areas (Farias et al., 2001), pollution from city sewage discharged without any previous treatment and the enrichment of the receiving body by bad management, are well-known, there is also a lack of systematized information on the water quality of Teles Pires river where the studied fish farm lies. Current analysis ensures the evaluation of water quality and fish farm system control in the northern region of the state of Mato Grosso at Paranaíta.

Study area

Research was developed on the Pappen fishing farm, in the town of Paranaíta (9° 32' 47.5" S; 56° 27' 51.6" W), in the extreme north of the state of Mato Grosso. Water samples were collected at seven sampling sites, as follows: site 1 (P_1) lies at the start of the water supply channel, protected by riparian vegetation and free from cattle; site 2 (P_2) lies on the main outlet of reservoir 2 (R_2); site 3 (P_3) lies in the channel which discharges from reservoir 2 (P_2); site 4 (P_4) lies at the outlet of reservoir 4 (R_4); site 5 (P_5) lies on the river, upstream the discharge from the fish farm; site 6 (P_6) lies at the end of the fish farm system which fills the tanks and receives water from other ponds and other refuse from fish processing; the 572m channel contains aquatic plants and discharges residues of fish culture directly into the river; site 7 (P_7) lies downstream from the fish farm discharging site in the river with a depth ranging between 0.7 and 2.4m (Fig. 1).

Material and methods

Management

The ponds and reservoirs were populated with cachara (Pseudoplatystoma fasciatum), tambaqui (Colossoma macropomum), pacu (Piaractus mesopotamicus), tambacu (Colossoma macropomum x Piaractus mesopotamicus), piau (Leporinus obtusidens), matrinxã (Brycon cephalus), curimba (Prochilodus lineatus), pintado leopardo jundiá (Leiarius marmoratus), at a density of 0.15 $Kg.m^{-3}$ Continuous water flow comes from water at the source. Fish were fed a supplementary diet containing 15% crude protein, at rates of 3% average live weight. The area, in which production system of aquatic organisms lies also, comprises a 60-head cattle herd, 70% of which are adult animals and the others of different age brackets. Cattle use water for drinking and move about natural lanes formed by the river Porto de Areia.

Physical and chemical data

Water samples were collected at 10 cm, monthly between April 2004 and February 2005. All samples were collected, at the same site, between 0900 h and 1100 h, with a 5L Van Dorn bottle. Nitrate, nitrite, total phosphorous and orthophosphate were determined according to Golterman et al. (1978). Ammonia, chlorophyll-a, alkalinity, hardness and total suspended solids (TSS) were determined according to Koroleff (1976), Nush (1980), Mackereth et al. (1978) and Boyd & Tucker (1992), respectively. Temperature, dissolved oxygen, pH and conductivity were measured in situ by a water quality checker Sper Scientific 840041, Oakton 35624-10, F-1000, respectively. Data on daily precipitation were measured by a pluviometer on the fish farm; day light periods, sunrise and sunset were also reported.

Morphological characteristics

Transects, approximately parallel to the length axis of the reservoir, were made. Bathymetric data were first transformed into a regularly spaced grid and further submitted to kriging to create depth contour lines through the use of Global Position System (Garmin – GPS 76). Data were obtained by CCD sensor (charge-coupled device) of CBERS-2 (China- Brazil Earth Resources Satellite) of point/orbit 168/111 and passage date 14/06/2005, supplied by the National Institute of Spatial Research

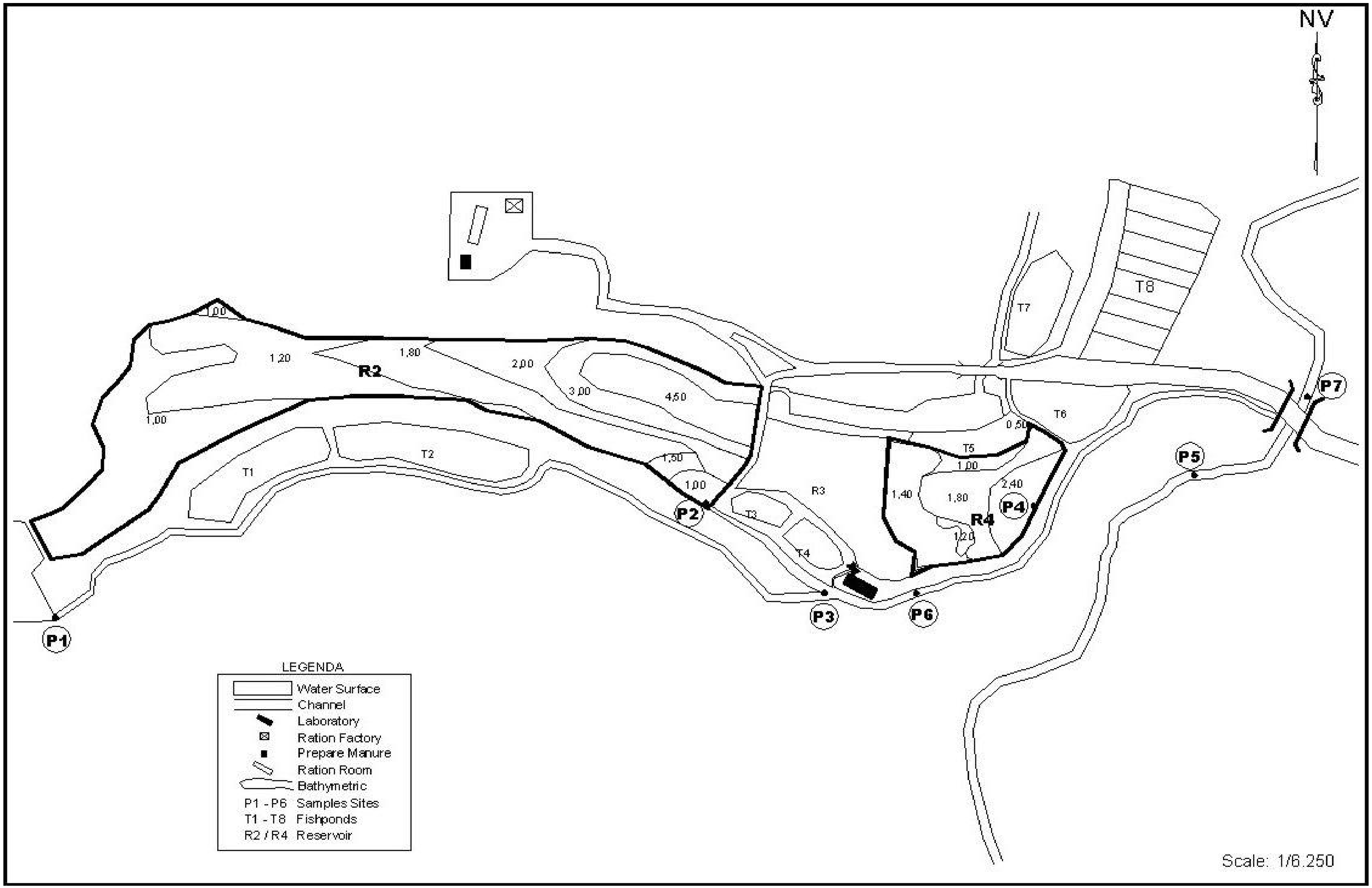

Figure 1: Bathymetric map of fish farm. Dark line indicates the limits of reservoirs (R_2 and R_4); fine lines indicate differences in depth.

(INPE) after correct processing of the images; colored compositions were produced on a 1/100.00 scale.

Statistical analysis

Two-way ANOVA analysis was applied to physical and chemical variables to compare sites and periods, and the interaction between them (Fowler et al., 1998).

Results

Physical and chemical data

Lowest dissolved oxygen concentrations were reported at sites P_2 (2.4 mg.L^{-1}) and P_4 (2.1 mg.L^{-1}) in November and July; highest concentrations were reported at P_3 (6.8 mg.L^{-1}), P_4 (7.0 mg.L^{-1}) and P_6 (6.7 mg.L^{-1}) in June, April and August, respectively. Dissolved oxygen concentrations were not different ($p<0.05$) during the experiment period. Conductivity rates were higher at P_4 until April, varying between 35.2 and 52.3 mS.cm^{-1}; this site was different ($p<0.05$) from the others. Lowest rates were observed at P_3, varying between 13.0 and 32.2 mS.cm^{-1}. Difference ($p>0.05$) in pH was not reported among sites, varying between 6.0 and 9.2 during the experimental period. Temperature varied between 25.1°C and 33.2°C, with a slight increase during the dry season (Tab. I; Fig. 2).

At the start of the experiment, hardness was highest at P_4, when compared to other sites, and varied between 25.1 mg.L^{-1} (April) and 26.7 mg.L^{-1} (July). Highest hardness concentration was observed in November (39.8 mg.L^{-1}) at P_7. Alkalinity was highest at the start of the experiment but tended to decrease as from November. All sites had an alkalinity concentration peak in May and June, varying between 44.6 and 61.2 mg.L^{-1}. As a rule, alkalinity at site P_4 was highest than that at the other sites. Highest TSS rates were observed in October at site P_4, or rather, 139.4 mg.L^{-1}. Highest values, or rather, 87.6 mg.L^{-1} and 71.0 mg.L^{-1}, respectively, were reported at sites P_5 and P_7, during the same month. As a rule, TSS rates were over 15 mg.L^{-1}, albeit similar ($p>0.05$) for all sites (Figs. 2 and 3).

Ammonia was the most abundant nitrogen compound at sites, with lowest rate at P_7 (between 6.7 and 71.8 mg.L^{-1}) and highest concentrations at P_2, with its peak in July with 210.3 mg.L^{-1}. Nitrite was the least abundant and its highest concentrations occurred at P_2 (7.0 mg.L^{-1}) and P_6 (8.0 mg.L^{-1}). Sites P_1 and P_2 were different ($p<0.05$) during the experimental period. Nitrate concentrations tended to rise as from November and maintained themselves higher than the ammonia concentrations at site P_5 (Tab. I; Fig. 3).

Table I: The mean, maximum, and minimum (between parenthesis) values of limnological variables, during the experimental period, in the different sites (P_1-P_7) of the fish farm.

Sites	Limnological Variables				
	pH	Temperature (°C)	Ammonia (µg.L^{-1})	Orthophosphate (µg.L^{-1})	Total Phosphorus (µg.L^{-1})
P_1	6.9 (6.0 - 7.7)	30.3 (28.0 - 33.0)	46.5 (10.6 - 73.5)	4.1 (3.3 - 22.2)	11.9 (1.0 - 46.9)
P_2	7.3 (6.5 - 8.3)	31.4 (29.2 - 33.2)	105.3 (15.5 - 375.9)	7.6 (5.0 - 19.4)	23.0 (8.5 - 60.0)
P_3	7.5 (6.7 - 8.1)	32.5 (28.7 - 33.1)	39.2 (3.9 - 73.0)	1.2 (2.5 - 5.0)	13.7 (3.7 - 60.9)
P_4	7.6 (6.8 - 9.2)	32.5 (27.6 - 33.0)	48.9 (7.0 - 135.2)	44.1 (3.0 - 143.9)	91.5 (18.1 - 300.6)
P_5	7.3 (6.5 - 8.0)	27.1 (25.1 - 33.0)	34.0 (11.7 - 68.2)	1.2 (2.2 -5 .0)	9.0 (1.1 - 24.2)
P_6	7.0 (6.0 - 7.7)	31.2 (25.8 - 32.4)	87.0 (42.3 - 275.6)	3.2 (3.0 – 9.3)	21.8 (8.5 - 131.6)
P_7	7.4 (6.0 - 8.8)	28.7 (25.4 - 33.0)	30.2 (6.7 - 71.8)	2.6 (2.7 - 9.6)	41.2 (4.5 - 355.3)

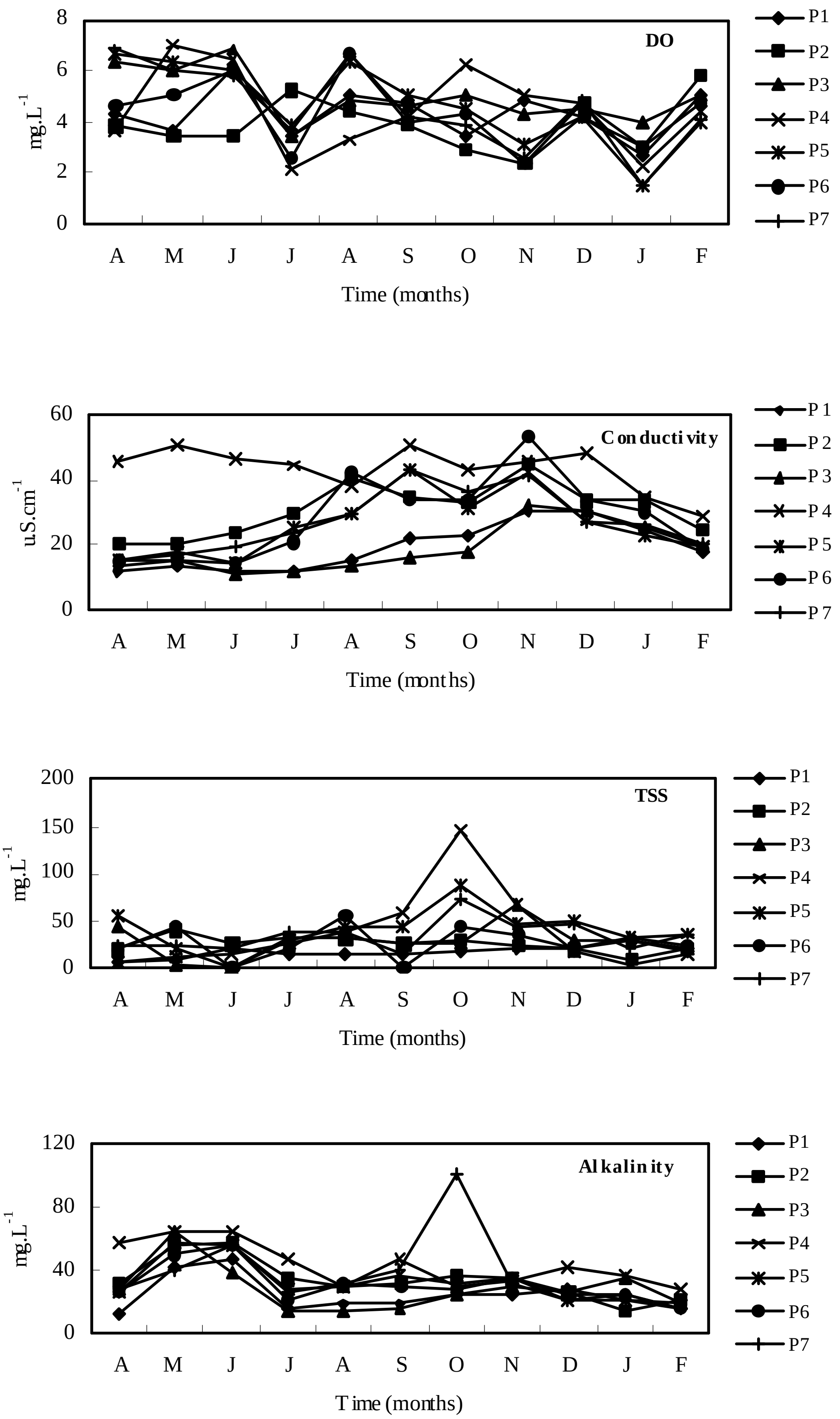

Figure 2: Fluctuation of dissolved oxygen, conductivity, and total suspended solids (TSS) alkalinity, during the experimental period, in the different sites (P_1-P_7) of the fish farm.

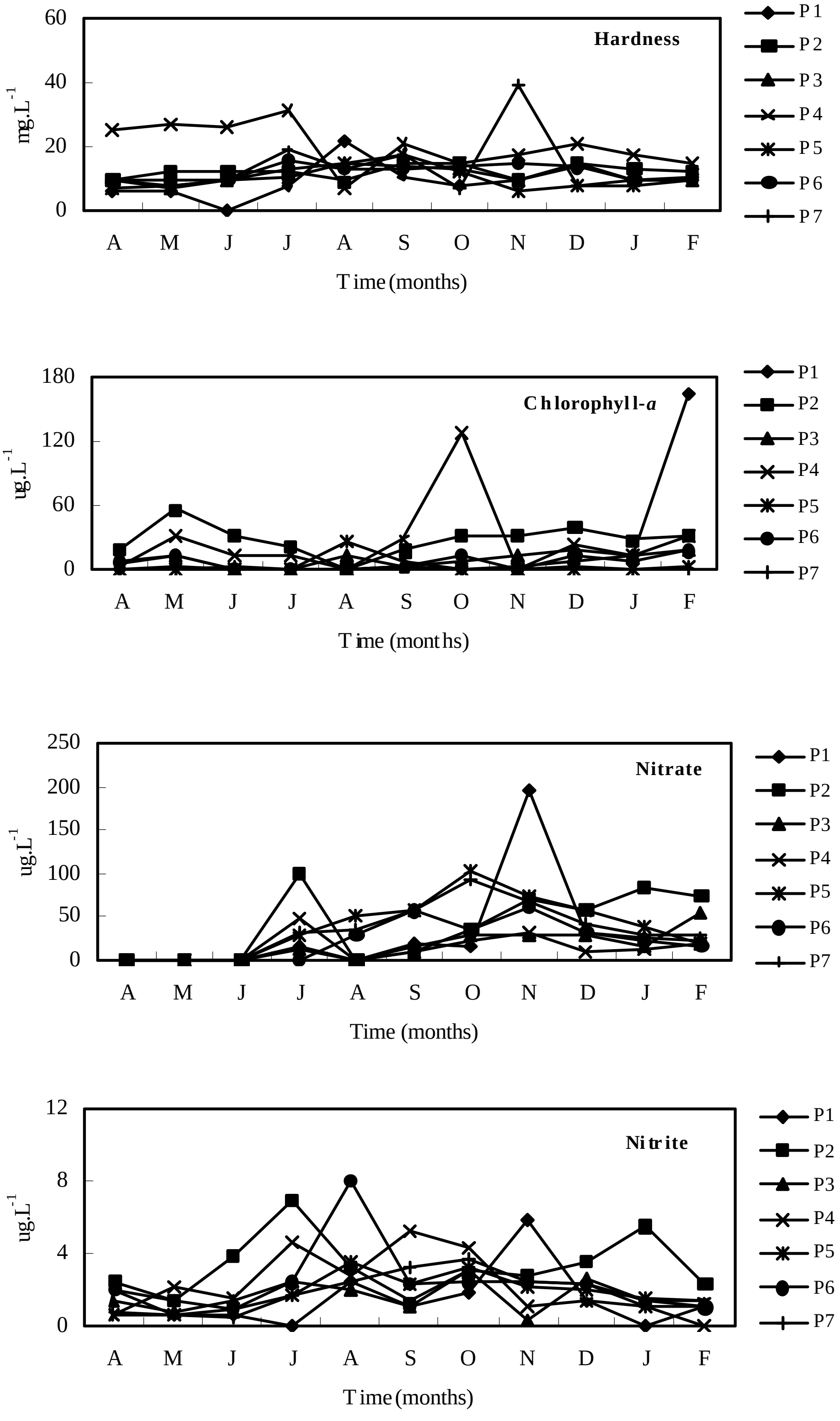

Figure 3: Fluctuation of hardness, chlorophyll–a, nitrite, and nitrate during the experimental period, in the different sites (P_1-P_7) of the fish farm.

Differences ($p<0.05$) for total phosphorus and orthophosphate have been reported between site P_4 and the other sites, with variations between 18.1 and 300.6 $mg.L^{-1}$, and between 3.1 and 143.9 $mg.L^{-1}$, respectively. A high concentration in total phosphorus (355.3 $mg.L^{-1}$) occurred in site P_7. Significant differences ($p<0.05$) in chlorophyll-a between sites P_2 and P_4 and sites P_5 and P_7 were found. Chlorophyll-a concentrations were similar ($p>0.05$) at the other sites during the experimental period. Highest abundance of chlorophyll-a occurred in July at site P_1 (164.1 $mg.L^{-1}$) (Tab. I; Fig. 3).

During the rainy period, from October to February (276.6 $mm.month^{-1}$), mean temperature, pH, conductivity, nitrate, chlorophyll-a and TSS rates were higher than those for the dry period ($p>0.05$). In the dry period, from April to September (72.2 $mm.month^{-1}$), mean rates of variables such as dissolved oxygen, alkalinity, ammonia, orthophosphate and total phosphorus were higher than those registered during the rainy period ($p<0.05$). As a rule, during the dry period, variables under analysis showed rising rates when P_1 (water supply) is compared to P_6 (discharge channel). Discharge P_6 affected receiving body P_7 in hardness, orthophosphate and total phosphorus during the rainy season and in orthophosphate during the dry season ($p>0.05$).

Morphological characteristics

Figure 1 shows a bathymetric map of the entire fish farm. Reservoir R_2 (P_2) margins have topographic irregularities; surface area is 11.02 ha; maximum depth 4.5 m and minimum depth 1.00 m; volume $20.11x10^2$ m^3. R_2 has a slightly conic form and wind effects are more pronounced than in other compartments. Reservoir R_4 (P_4) is shallow with maximum depth 2.40 m and minimum 0.50 m; irregular margins, volume $4.58x10^2$ m^3. It has riparian vegetation within the compartment, parallel to the river Porto de Areia and is protected from winds coming from this direction. Total area of fish farm is 64.87 ha, included tanks and reservoir. Sites P_1, P_3 and P_6 lie at the supply and discharge channel, 2,250 m long and average depth 0.5 m.

Discussion

Low rates of dissolved oxygen and high concentration of ammonia at P_4 in July may be due to food increase hailing from high availability of nutrients from excretion and gas exchange. Due to low population density and when compared to total area and species volume, no decrease in dissolved oxygen in P_2 was reported. Low concentrations of this variable in November were probably due to less sunshine during the day in which sampling was taken. Low fish stock density in tanks impaired the environment from being eutrophic (Souza et al., 2000).

Increasing rise of nutrients from July to September in P_4 may be due to feeding processes and shifting of sediment which occurred on the gradual removal of fish to populate other tanks. This fact caused availability of nutrients in the sediment which stimulated the production of phytoplankton and an increase in chlorophyll-a. Dissolved nutrients stimulate the production of phytoplankton in tanks and a substantial increase in organic matter (El-Shafai et al., 2004).

The removal of fish from Reservoir 4 (P_4) caused an increase in chlorophyll-a and a gradual decrease in phosphorus and orthophosphate during September and October. Data are corroborated by nitrogen compound index, mainly ammonia, which decreased during the same period. An inverse behavior occurred with regard to the relationship between nitrate and nitrate in the same period. This is probably due to the activities of nitrifying bacteria that transform the available nitrite into nitrate (Sugita et al., 2005).

High TSS, nitrate and nitrite rates reported at P_5 and P_7 during the dry period may have been caused by cattle that drink from the river water and eventually excrete and urinate in the whereabouts. In fact, there is an area used for cattle drinking and movement upstream the above-mentioned sampled units. Decrease in rates of the above variables has been reported as from October, owing to rainfall increase which, as a consequence, produced a greater dissolving rate of the compost. As from October increasing nitrate rates at P_2 coincide with nitrite and ammonia oscillations which may be explained by ration feeding and control of R_2. Nitrite rates in P_1 are different from those in P_2, since it is a supply reservoir. High ammonia and total phosphorus concentrations at P_6 have been reported since they receive the overflow of the entire fish culture system, which comprises the fish processing site. Actually P_7 (river) is not significantly affected by P_6, upstream P_7, although the former lies in a 572m channel with slight meanderings and dense aquatic vegetation. It may be accountable for the retention or the absorption of organic and inorganic material. Cultivated river beds maintain the water quality by removal and retention of nutrients, by the processing of organic material and chemical residues and by the reduction of sediment discharge in the receiving bodies (Hussar et al., 2005).

Increasing rates of environmental variables from P_1 to P_6, mainly during the dry period, may be associated to the low dissolution discharge owing to less rainfall at this time, of the year and also to fingerling activities and fishing processing upstream P_6.

According to Colosso et al. (2003), concentration of soluble phosphorus in water of effluents increases during the first hours after feed and decreases after 4 or 6 hours. Rates at P_2 may be due to feeding, since samplings were undertaken at the first evening hours and ration-taking during the morning period.

Conductivity in P_3 showed mean rates which were lower than those in P_2 and P_1. Conductivity was affected by large amounts of macrophytes in the channel that conducts water from P_2 to P_3, caused by the removal of ions from the water. According to Chernicharo (2001), when water flows through the substratum, vegetation impairs the water course, diminishes the speed of flow towards the receiving body and precipitates the sediment and the suspended particles.

Low alkalinity and pH in P_1 may be related to the fact that the reservoir has been built for the water supply system. Further, no chemical or organic treatment has been given to the water during the period under analysis. In the Amazon region water for fish culture has low concentration of dissolved salts (Araújo-Lima & Goulding, 1997; Brandão et al., 2004). With the exception of P_4, the highest rate of the above variable in all sections of the system refers to P_7, which may be associated to the fact that 5 tons of fish were slaughtered the day previous to water sampling. This event may have made the rates of the variables different.

Hardness variations at P_1 and P_4 may be explained by the specificities of each system or rather P_1 is the supply source and has natural characteristics, whereas the function of P_4 is the production of water organisms which receive previous treatment before being placed. In the case of P_7 (downstream), on the other hand, mean hardness rates have been affected by direct control of the fish culture under analysis and by that of the river (P_5 - upstream).

Hardness, conductivity and alkalinity oscillation patterns may be attributed to soil liming during the initial period, with subsequent decrease of rates in P_4. Moreover, water in P_4 merely functions for level maintenance to compensate losses through infiltration and evaporation. Highest TSS rates were obtained during fish removal when sediment revolving occurred with a subsequent increase in TSS concentration in the water.

Chlorophyll-a variation at P_2 and P_4 may be explained by indexes of nitrogen compounds during the period. A decrease in chlorophyll-a production associated with a decrease of nitrogen compounds has been reported. Similar findings have been reported by Sipaúba-Tavares et al. (2003) who registered high rates of physical and chemical variables, with the exception of chlorophyll-a and nitrogen compounds in ponds covered by the macrophyte Salvinia sp. Low rates in the sampled points of the river may be due to lower concentrations of nutrients in lotic environments when compared to those in production systems of aquatic organisms. In continuous water flow environments nutrients are carried away and, consequently, phytoplankton density, manifested by low chlorophyll-a concentration, diminishes (Souza et al., 2000).

Henry-Silva & Camargo (2006), showed that pond effluent quality improved after treatment with aquatic plant, with decreasing of phosphorus and nitrogen.

The fact that water passes through a vegetation-covered channel with positive effects in fish culture water discharge. Mean rates of some variables in P_7 (downstream) were similar to those in the river (P_5 - upstream), with the exception of orthophosphate, total phosphorus, alkalinity, hardness and conductivity. Changes were not significant ($p>0.05$).

Sipaúba-Tavares & Boyd (2005) verified that kind of vegetation growing in and along the edges of shallow ditch, provide some degree of aquaculture effluent treatments.

The use of aquatic plants to treat aquaculture effluents valuable an appropriate technology with relative low cost, and the wetlands are dynamic systems unless human intervention arrests these processes (Shutes, 2001).

Dry and rainy periods showed that highest changes in the quality of system's discharge occurred in the months with less rainfall. However, rates are within the limits (TP=0.05 $mg.L^{-1}$; Ammonia = 2.0 $mg.L^{-1}$) laid by CONAMA (2005) Resolution 357, typifying as class 2 the effluent with the above variables.

However, in every system fish hauling practice brings about high limnological variables, making mandatory the use of adequate control practices. Although effluents are within the established legal patterns, probable changes in the river may be related to discharges from the fish culture system with the consequent and progressive worsening of water quality of the receiving body. Since pollution level caused by fish culture is closely linked to tank control, food and fish processing system, adequate practices in system control will comprise a rational water management and an improvement in the quality of effluents, especially during the dry period when discharge is at its lowest and, consequently, the self-purifying factor of the receiving body is on the decline.

Acknowledgments

The authors wish to thank Silvia R. L. de Laurentiz and Tatiana Betioli Fioresi for the laboratory assistance, and the Pappen family (fish farm) for its logistical support involved in the experiment.

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Received: 12 February 2007
Accepted: 31 January 2008